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FINAL REPORT

Sea-Ice Classification by the Intelligent Integration of Active and Passive Microwave Data

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In this final report we summarize all products and research accomplishments resulting from the project funded by NASA Headquarters under grant NAGW-3043.

The goal of the project was to develop and implement algorithms that would analyze satellite SAR imagery of sea ice. Initially the goal was to concentrate on the intelligent classification of sea ice into types (open water, thin ice, first-year ice, multiyear ice, and so forth). As the project progressed, we also developed algorithms that generate other sea ice parameters that are of operational and scientific interest.

Our accomplishments can be summarized as follows. We developed and fully tested:

1. a fully integrated system, named ISICLE, which uses dynamic thresholding, feature extraction, and expert systems to classify sea ice into open water/thin ice, first-year ice, and multiyear ice during the winter, and into ice/no-ice during the summer and in the MIZ.
2. an algorithm that, given a classified sea ice image, identifies the leads and computes all lead parameters of interest.
3. algorithms to perform texture analysis of sea ice and an extensive study that identified the best mathematical models to compute and represent sea ice texture
4. an algorithm that computes the size of the sea ice floes in an image and calculates their size distributions.
5. an algorithm that computes total ice concentration ("ice/no-ice" algorithm).
6. an algorithm that uses neural networks to track sea ice floes in the marginal ice zone and during the summer melt.
7. In parallel with the development of algorithms we systematically documented microwave signatures of sea ice during various seasons.

Our research has always been result driven, and our algorithms and code have been used by other researchers in their own work:

1. our dynamic thresholding algorithm was used in the dissertation work of Scott Beaven at the University of Kansas
2. our dynamic thresholding and feature extraction algorithm was used in the work of H.G. Sohn and Ken Jezek at Ohio State University (reference: "Ice Sheet Margin Detection Using ERS-1 Synthetic Aperture Radar", IGARSS'96)
3. our floe size extraction algorithm was used by Ben Holt of JPL and Seeley Martin of the University of Washington who studied summer melt phenomena in the MIZ (reference: "Measuring Sea Ice Floe Size During Summer with ERS SAR Imagery", IGARSS'96)

4. our floe size extraction algorithm was also used by Martin Ouellet and Luc E. Chouinard of the Dept. of Civil Engineering and Applied Mechanics of McGill University, who wanted to generate statistics of the floes around the Canadian waters from aircraft SAR images.
5. the Canadian and U.S. Ice Centers are considering to use our dynamic thresholding, ice/no-ice, and floe size algorithms to generate regular operational products

Our work has generated a lot of interest at the U.S. and Canadian Ice Centers, since our algorithms are fast and extensive testing has shown that they generate parameters that are of immediate operational interest.

We have cooperated very closely with other researchers in the area to learn from them and to transfer our work. Students supported by the grant have spent as much as three months at ASF, the National Ice Center, JPL, Goddard SFC, and Stennis SFC.

Our work has been published extensively in the last three years. Our results appeared or will appear in two book chapters, three journal articles, and in nine conference proceedings and four workshop presentations.

The grant has supported fully or partially seven graduate students and two undergraduate students, five of which graduated with a Master's of Science degree, and three of which are graduating with a Ph.D. degree. Additionally, an undergraduate student from Virginia Polytechnic Institute (currently attending Stanford for his M.S. degree), funded by an NSF grant for Research Experiences for Undergraduates, participated in the project for one summer.

We attended many GPS, RGPS and RADARSAT meetings, and became involved in the RGPS Team (1993-present) and in the GPS Sea Ice Classification Validation Team (1992-1994).

Finally, our involvement in the sea-ice community led directly to us editing a book together with Dr. Ron Kwok of JPL. The book, tentatively titled "Automated Analysis of Sea-Ice SAR Data", will be published in 1997 by Springer-Verlag, and will contain the most recent and advanced work in the automated analysis of satellite SAR for sea-ice applications.